REMARKS

The specification has been amended to include a cross-reference to related application and to include headings to bring into better U.S. form.

The above amendments to the claims are being made to eliminate multiple dependencies and bring the claims into better U.S. form. The amendments do not add to or depart from the original disclosure, or constitute prohibited new matter.

Respectfully submitted,

By: ______________________

George R. Repper
Attorney for Applicants
Registration No. 31,414
ROTHWELL, FIGG, ERNST & MANBECK, P.C.
Suite 800, 1425 K Street, N.W.
Washington, D.C. 20005
Telephone: (202) 783-6040

SUBSTITUTE SPECIFICATION (MARKED-UP VERSION)

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~~DESCRIPTION~~

CLADDING

BACKGROUND OF THE INVENTION

CROSS-REFERENCE TO RELATED APPLICATION

[001] This application is a National Phase of International Application Serial No. PCT/GB2004/003846, filed 9 September 2004.

Field of Invention

[002] The present invention relates to a cladding for suppressing vortex induced vibration of underwater pipes, cables or other elongate members.

Description of the Background Invention

[003] When water flows past an underwater pipe, cable or other elongate member, vortices may be shed alternately from either side. The effect of such vortices is to apply fluctuating transverse forces to the member. Such forces can cause the member to bend more than is desirable and impose unwanted additional forces on the member's point of suspension. If the shedding frequency of the vortices is close to a natural frequency of the member then resonance effects can result in particularly severe and potentially damaging oscillation. The problem is experienced particularly in connection with marine risers of the type used in sub-sea oil drilling and extraction. It is referred to as "vortex induced vibration" or "VIV".

[004] It is known to apply to elongate underwater members a cladding whose exterior is shaped to suppress VIV. Reference is directed in this regard to UK patent application No. 9905276.3 (publication No.2335248, CRP Group Limited) which discloses an underwater cladding made up of a number of separately formed sections assembled to form a tubular structure receiving an underwater member and having sharp edged helical strakes along its length which, by controlling transition from laminar to turbulent

in a flow of water on the structure, serve to suppress VIV. The sections are moulded from polyurethane and are semi-tubular, a facing pair of such sections being assembled around the underwater member to surround it.

[005] The cladding has proved itself in practice to be highly effective. However there are commercial pressures to produce a unit which is more economical in manufacture than the existing polyurethane cladding. Additionally the existing cladding has moderately thick walls which add to its mass and also to the area it presents to a flow, so that drag is increased. Reducing the mass and frontal area are desirable.

[006] The present inventors have recognized that the technique of rotational moulding can be advantageously applied to the manufacture of cladding for underwater members.

[007] Plastics materials used in rotational moulding, such as polyethylene, tend to be vulnerable when submerged in seawater to marine fouling-accretion of largely biological material on their surface. Initial soft marine fouling is followed by hard fouling. It is known to reduce or even prevent fouling by incorporation into submerged structures of biocides with anti-microbial properties. Copper (1) ions are highly toxic to aquatic organisms. Cuprous compounds are in widespread use, particularly in paint compositions, for prevention of marine fouling on sub-sea and tidal-zone installations. However there are particular problems to be addressed in incorporating anti-fouling compounds into a rotationally moulded cladding:-

[008] i. design lifetime can be in excess of 20 years. Anti-fouling compositions are typically leached into the surrounding water. To achieve satisfactory anti-foul effect can require cuprous oxide loading of 20-30% by mass in a polyethylene moulding;

[009] ii. density is greatly increased by this level of loading. Medium density polyethylene has some inherent buoyancy, with typical specific gravity of 0.93. Cuprous oxide however has a specific gravity of 6·0.25% cuprous oxide loading thus results in a material with a specific gravity of 1.18. Sea water varies around 1.022. For typical sub-sea cladding installations the resulting negative buoyancy - and consequent additional

weight loading upon the clad member - would be unacceptable;

[0010] iii. material properties are impaired by anti-fouling compounds. The toughness and durability of polymer materials would be significantly compromised by incorporation of a high loading of inorganic material; and

[0011] iv. cost is significantly increased by use of expensive anti-fouling compounds.

[0012] The provision of an improved method of manufacture of an anti-V.I.V cladding, and of an improved anti-V.I.V. cladding as such, are objects of the present invention.

[0013] Patent Office searches to date have cited GB 2378969 (Balmoral Group Limited), which concerns a hollow, cylindrical vortex-induced vibrating suppression unit having a relatively deep wall containing helical grooves for the purpose of V.I.V. suppression. There is a brief mention of rotational moulding as one of several techniques which could be used to manufacture the unit, but no mention of the problem of fouling or of measures to address it. The same search cited GB 2363363 (Shell International Research Maatschappij B.V) and GB 2362444 (CRP Group Limited) both of which concern cladding with V.I.V. suppression strakes upon semi-cylindrical cladding sections, but neither of which proposes rotational moulding thereof nor addresses the fouling problem.

SUMMARY OF THE INVENTION

[0014] In accordance with a first aspect of the present invention there is a vortex induced vibration suppression cladding section for mounting upon an elongate underwater member, the section comprising a plastics moulding shaped to provide a tubular portion for receiving the member, the tubular portion being split along its length and being deformable to permit the member to be introduced into the tubular portion, the cladding section comprising at its exterior at least one feature shaped to suppress vortex induced vibration, and the cladding comprising an outer layer incorporating anti-fouling material and an inner structural layer.

[0015] In accordance with a second aspect of the present invention there is a method

of manufacturing a vortex induced vibration suppression cladding section for mounting upon an elongate underwater member, the method comprising rotationally moulding an outer layer comprising plastics material incorporating anti-fouling material, and subsequently rotationally moulding an inner structural layer comprising plastics material within the outer layer, so that the two layers form a unitary moulding.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

[0017] Fig. 1 is a perspective illustration of a section of VIV suppression cladding embodying the present invention;

[0018] Fig. 2 is a section in a radial plane through part of the section of cladding illustrated in Fig. 1;

[0019] Fig. 3 is a perspective illustration of a pair of such sections assembled in a string; and

[0020] Fig. 4 is a section through a wall of a cladding embodying the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0021] The illustrated cladding sections are manufactured by the rotational moulding process which is in itself well known and will only be very briefly explained herein. Rotational moulding is distinguished from other moulding techniques in that during the moulding process the mould is rotated, so that the material in it forms a layer over the mould's inner surface. It is not intended to imply that the present invention is limited to any particular rotational moulding technique. However it may be further explained that rotational moulding typically involves introducing a measured quantity of thermoplastic powder to the mould and then heating the mould and rotating it. As the mould rotates the powder tends to fall to the bottom due to gravity. The heat of the mould causes the powder to form a unitary wall on the mould's interior, a process akin to sintering. Liquid resin may be used in place of powder, curing of the resin being promoted by the heated

wall of the mould. Rotation may be about two axes. Alternatively, in the so-called "rock and roll" process, well suited to manufacture of elongate items such as the present cladding, the mould is eccentrically mounted so that rotation about a generally horizontal axis causes the mould to rock and so serves to distribute material along the mould's length. The result is a hollow moulding with a controlled wall thickness which, after cooling (e.g. by air or water jets) can be removed from the mould.

[0022] The illustrated cladding sections have been manufactured in one piece by rotational moulding in polyethylene, an economical material which is tough and of moderate density similar to that of water, so that the sections are approximately neutrally buoyant.

[0023] Each cladding section 8 comprises a tubular part 10, which in the present embodiment is of circular cross section, and integrally formed VIV suppression features which in the present embodiment are formed as strakes 12. The wall of the tubular part 10 is longitudinally split at 14 and by virtue of the resilience of the material from which it is made, the section can be opened out - that is, the two sides of the split can be drawn apart - to allow the cladding section to be placed around an elongate member such as a marine riser.

[0024] The strakes 12 are best seen in Fig. 2 and have an exposed vertex 16 which tends to "trip" flow over the cladding - ie. to promote the transition from laminar to turbulent flow. The resulting controlled transition from laminar to turbulent flow typically does not give rise to vortex induced vibration. The illustrated strakes are of triangular cross section. It can be seen that they are hollow. This is a result of the rotational moulding process. The strakes protrude from the exterior of the tubular part and extend along its length but form a helix of shallow pitch. There are three parallel strakes arranged in the manner of a triple start screw thread. The result is that the cladding is equally effective for suppression of V.I.V. in flows from any direction. Where a line of strakes crosses the split 14 in the tubular part 10, as at 21 in Fig. 1, the strake is omitted from that region.

[0025] In use several sections are placed end-to-end in a string covering a length of the

elongate underwater member. Ends of each section are provided with complementary mating features so that they can be fixed together. These take the form of stubs 18 in the illustrated embodiment but it is anticipated that in a production version there may simply be a "joggle" - an enlarged diameter section at one end of each section to form a socket receiving the non-enlarged adjacent end of the neighboring section.

[0026] The cladding can be secured in place by means of tension bands placed around it at intervals along the cladding's length. Note that the strakes are interrupted e.g. at 20, 22 to permit the bands to be applied without crushing the strakes. Suitable bands are known in this art. Typically a band is applied around each of the junctions between adjacent sections to secure them together.

[0027] Prototype cladding of the illustrated type have been found to be more than four times lighter than equivalent polyurethane cladding. The thin walls and hollow strakes of the illustrated cladding contribute to this weight reduction. As a consequence of its low weight, the illustrated cladding is relatively easy to handle and install.

[0028] It is desirable to provide the cladding with protection against marine fouling - accretion of biological material on its surface. This can be advantageously achieved in a cladding embodying the present invention by a moulding technique referred to as "double shotting". In this technique the wall of the moulding is built up in two layers. Firstly an anti-fouling material is introduced to the mould and forms an outer layer of the moulding which can be relatively thin. A structural inner layer is then formed by introducing a different material - in this case polyethylene - and continuing the rotational moulding process. The anti-fouling material forming the outer layer is relatively expensive but the technique allows good use to be made of this material.

[0029] Figure 4 illustrates a portion of a wall of this multi-layer cladding in section. In this example a total wall thickness of 4mm is made up of a 1mm deep outer layer 24 comprising polymer material (polyethylene, in this case) with an admixture of anti-fouling material in the form of particulate cuprous oxide. The cuprous oxide forms 20-30% of the mass of the outer layer 24. An inner polymer layer 26 lacks anti-fouling material and is in this example formed of polyethylene. This is relatively low in density

and cost. The cladding can overall have a neutral or even positive buoyancy in sea water.

[0030] Various materials may be used in claddings embodying the present invention. The structural polymer need not be polyethylene. Many thermoplastics are suitable, including (but not restricted to) PET, Nylon, PVC, Styrene, and all Polyolefins. The anti-fouling composition need not be cuprousoxide as such. Many cuprous compositions are suitable and could be used, including cuprous thiocyanate, copper pyrithione and commercially prepared anti-fouling compositions such as copper omadine (available from Arch Chemicals). Non-cuprous materials may also be used, eg. zine and tin complexes, and indeed organic biocidals, several of which are commercially produced for anti-fouling applications.

[0031] The double (or multiple) shotting technique can be used to provide the product with a shallow exterior coloured layer or with visual markings.

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